Response to anonymous referee 4

We thank the referee 4 for the detailed review. In this response, the reviewer's comments are in black standard font. Our response is in standard blue font and the modifications to the manuscript are in blue bold font.

Summary:
The authors estimate the total ablation associated to supraglacial ice cliff melt on the debris-covered tongue of Changri Nup Glacier, Nepalese Himalaya, based on high resolution topographical data. They use terrestrial photogrammetry surveys on selected cliffs for validation and UAV- and satellite-imagery for the entire cliff population on that glacier for two consecutive years. They then derive the contribution of ice cliff melt relative to glacier melt on the tongue of Changri Nup Glacier by taking into account emergence velocity and estimate ice cliff melt to be ~3 times higher than the average melt of the glacier tongue. They conclude that ice cliffs cannot explain the debris-cover anomaly and that the anomaly in turn could be a result of lower emergence velocities and reduced ablation.

General comments:
The main outcome of this study is that UAV- and especially high-resolution satellite imagery can be used to estimate glacier-wide volume losses associated to ice cliff melt, as the authors showed by a sophisticated analysis of various topographic datasets. The second important conclusion of the study is the fact that emergence velocities have so far not been considered carefully enough in terms of glacier ablation estimates and should be investigated further. However, as much as I appreciate the topic of the paper including all its careful analysis, I think the authors' main conclusion of explaining the debris-cover anomaly with reduced emergence velocities in general is not appropriate and a bit out of the context of the paper, given the limited sample size of just one glacier tongue. I suggest the authors adapt the title accordingly and focus more on the nice outcome of the cliff volume loss estimates at the glacier scale, especially in the discussion of the manuscript. Further, I think the balance between ice cliffs and emergence velocity is not given, as the main part of the paper regarding methods description and results, is mostly about ice cliffs and in contrast the discussion/conclusion part is mostly about emergence velocities. The processing of the ice cliff data is well described in general and the results are elaborated carefully by taking into account uncertainties. I miss a better description of one of the key improvements compared to an earlier study, the correction for distortion. Further, I am not convinced that the calculation of the p-factor is feasible or should be done in a different way. All in all my impression of the paper in terms of quality, writing, and relevance in the context of the actual literature is good and it fits into the scope of The Cryosphere, but I have major comments that should be addressed. If these are addressed, I am sure the paper will be a useful contribution to the glaciological community. See further comments below.
We thank referee 4 for her/his positive appreciation of our work. See our response to the comments below.

Main issues:

1) Explanation of "debris-cover anomaly"

I like that you bring the emergence velocity component into the focus of the analysis and interpretation of debris-covered glaciers. It is clear that this upward movement of parts of the glacier tongue has been neglected so far in most of the studies related to debris-covered glaciers especially. In the case of Changri Nup Glacier the emergence velocity is, based on your observations, very small and thus similar downwasting rates of debris-free and debris-covered glacier surfaces might be explained by this differential emergence. However, I am not convinced by the reasoning of the authors to generalize this result and explain the debris-cover anomaly solely by the confusion of glacier elevation changes and net ablation. It is not clear if Changri Nup Glacier has ablation rates similar to that of debris-free glaciers (of the same elevation range) at all, but this would be the case for the debris-cover anomaly.

The “debris cover anomaly” (i.e. similar thinning rates over debris-covered and debris free glaciers at similar elevations, although ablation is expected to be reduced over debris covered glaciers compared with debris-free glaciers) is to our opinion an interesting but fuzzy concept, which has been used to motivate previous studies that looked for processes responsible for enhanced ablation on debris-covered tongues. Based on the data of Brun et al. (2017), we show that the thinning rates of debris-covered areas are comparable to thinning rates of debris-free areas for glaciers in the Khumbu region (Figure R1). The thinning rate of Changri Nup Glacier agrees well with this regional pattern and therefore we do conclude that the tongue of Changri Nup Glacier is a representative “debris-anomaly” glacier.

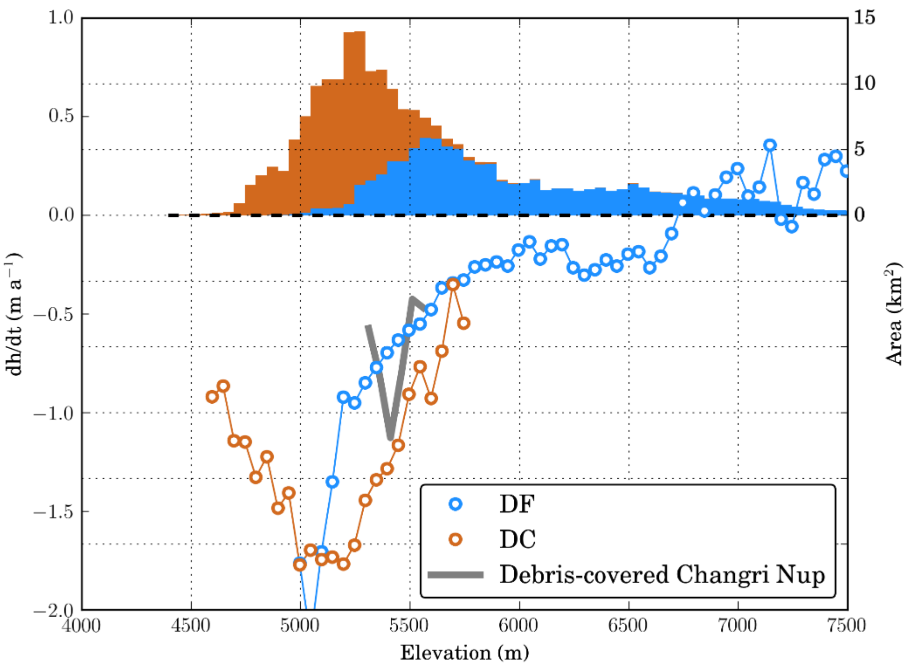

Figure R1: rate of elevation change for debris-free and debris-covered ice in the Khumbu region, based on Brun et al. (2017) data. . The brown histogram represents the hypsometry of the debris-covered ice and it is stacked above the blue histogram, which represents the hypsometry of the debris-free ice. The thinning rate for the debris-covered part of Changri Nup is overlaid in grey.

For sure emergence is an important component and might explain many issues related to this topic. But I think, just based on one single glacier making a general conclusion is too ambitious and therefore the title of the manuscript should be adapted accordingly, away from the debris-cover anomaly more towards the volume loss of the ice cliffs. The study still presents interesting points and provides nice results, such as: estimation of the volume loss associated to ice cliff melt at the glacier scale; incorporating rotational behavior of ice cliffs in volume loss estimates; sophisticated comparison to net ablation by taking into account also glacier emergence.

We agree with the reviewer’s comment and now avoid unsupported generalization, as also recommended by other reviewers. Consequently, the title of the manuscript was revised and now reads: “**Ice cliff contribution to the tongue-wide ablation of Changri Nup Glacier, Nepal, Central Himalaya**”. Additionally, section 6.3 regarding the debris-cover anomaly has been mostly rewritten, with much more caution regarding the generalization of our conclusions.

The manuscript now focuses more on the cliff evolution and contribution to tongue-wide ablation. Indeed, we extended the discussion section 6.1 ("**Cliff evolution and** comparison of two years of acquisition") and we added a table in the supplement (Table S2) showing the evolution of individual cliffs:

"The total area occupied by ice did not vary significantly from year to year, ranging from 70 ± 14 × 10^3 m^2 in November 2017 to 72 ± 14 × 10^3 m^2 in November 2016. The twelve individual cliffs surveyed showed large variations in area within the course of one year, with a maximum increase of 57 % for the large cliff 06 and a decrease of 34 % for cliff 03 and 09 (Table S2). The total area of these twelve cliffs increased by 8 % in one year. Interestingly, over the same period, Watson et al. (2017) observed only declining ice cliff area on the tongue of Khumbu Glacier (~6 km away). All the large cliffs (most of them are included in the twelve cliffs surveyed with the terrestrial photogrammetry) persisted over these two years of survey, including the south or south-west facing ones (Table 1) , although south facing cliffs are known to persist less then non south facing ones (e.g., Buri and Pellicciotti, 2018). However, we observed the appearance and disappearance of small cliffs, and marginal areas became easier to classify as either ice cliff or debris-covered areas, highlighting the challenge in mapping regions covered by thin debris (e.g., Herreid and Pellicciotti, 2018).

We calculated backwasting rates for the twelve cliffs monitored with terrestrial photogrammetry for the period November 2015-November 2016 (Table 1). The backwasting rate is sensitive to cliff area changes (because it is calculated as the rate of volume change divided by the mean 3D area) and should be interpreted with caution for cliffs that underwent large area changes (e.g., cliffs 01, 02, 03, 06, 09 and 11; Table S2). The backwasting rates ranged from 1.2 ± 0.4 to 7.5 ± 0.6 m a^{-1} , reflecting the variability in terms of ablation rates among the terrain classified as cliff (Fig. 9). The lowest backwasting rates are observed for cliffs 11 and 12, located on the upper part of the tongue, roughly 100 m higher than the other cliffs (Fig. 1 and Table 1). The largest backwasting rates were observed for cliff 01, which expanded significantly between November 2015 and November 2016. The backwasting rates are lower than those reported by Brun et al. (2016) on Lirung Glacier (Langtang catchment) for the period May 2013-October 2014, which ranged from 6.0 to 8.4 m a^{-1} and lower than those reported for surviving cliffs by Watson et al. (2017) on Khumbu Glacier for the period November 2015-October 2016, which ranged from 5.2 to 9.7 m a^{-1}. These differences are likely due to temperature differences between sites. Indeed, the cliffs studied here are at higher elevation (5320-5470 m a.s.l.) than the two other studies (4050-4200 m a.s.l. for Lirung Glacier and 4923-4939 m a.s.l. for Khumbu Glacier)."

2) Calculation of p

I am not sure if your calculation of the p ratio makes much sense. Like this you compare ice cliff melt to the melt of the entire debris-covered glacier tongue. This means you compare ice cliff melt to a mixture of subdebris- and ice cliff melt (the glacier tongue). Wouldn't it be more feasible to compare ice cliff melt to subdebris melt (i.e, exclude ice cliff areas)? In order to be comparable to the previous studies you cited, you should check if they also compared ice cliff melt to the ice cliff-subdebris mixture or to subdebris melt only.

This point was also mentioned by other reviewers, consequently the *p* factor is now named f_C factor to avoid a confusion with the "*p*-value". The f_C factor has the same definition as *p*, but we added the definition of a new factor, named f_C^*, which is the ratio of the cliff ablation divided by the non-cliff ablation (denoted by the subscript NC):

$$f_C^* = \frac{\Delta V_C}{A_C}\frac{A_{NC}}{\Delta V_{NC}} = f_C \frac{\Delta V_T}{\Delta V_T - \Delta V_C}\frac{A_T - A_C}{A_T}$$

Based on our data, for Changri Nup Glacier, $\frac{\Delta V_T}{\Delta V_T - \Delta V_C} = \frac{1}{1-0.23} = 1.30$ and $\frac{A_T - A_C}{A_T} = \frac{1-0.07}{1} = 0.93$, consequently $f_C^* = 1.2\, f_C$.

For the consistency between the studies mentioned, we interpreted the studies as follow:

- Juen et al. 2014 : “Although the ice cliffs occupy only 1.7% of the debris covered area, the melt amount accounts for approximately 12% of the total sub-debris ablation” -> $f_C^* = \frac{12}{1.7} = 7.1$
- Reid and Brock 2014: “Analysis of the DEM indicates that ice cliffs account for at most 1.3% of the 1m pixels in the glacier’s debris-covered zone, but application of a distributed model indicates that ice cliffs account for ~7.4% of total ablation.” -> $f_c = \frac{7.4}{1.3} = 5.7$
- Buri et al. 2016: “Although only representing 0.09% of the glacier tongue area, the total melt at the two cliffs over the measurement period is 2313 and 8282m3, 1.23% of the total melt simulated by a glacio-hydrological model for the glacier’s tongue. -> $f_c = \frac{1.23}{0.09} = 13.7$
- Sakai et al 1998: From the abstract: “The ice cliff melt amount reaches 69% of the total ablation at debris covered area, although the area of ice cliffs occupies less than 2% of the debris covered area” -> $f_c = \frac{69}{2} = 35$
- Sakai et al 2000: From their Table 2: ratio of the “absorbed heat at each type of surface during the observation period (167 days)”, including the “whole debris-covered zone” -> $f_c = \frac{256}{26} = 9.8$ or looking only at the debris -> $f_C^* = \frac{256}{21} = 12.2$
- Brun et al 2016: “The ice cliffs lose mass at rates six times higher than estimates of glacier-wide melt under debris, which seems to confirm that ice cliffs provide a large contribution to total glacier melt.” -> $f_c = 6$
- Thompson et al 2016: “Although ice cliffs cover only ~5% of the area of the lower tongue, they account for 40% of the ablation.” -> $f_c = \frac{40}{5} = 8$

As most of the studies were already within the framework of the original definition of p/f_C, we decided to keep the focus on this factor, instead of f_C^*. This example demonstrates the importance of a consistent framework for comparing these studies.

Consequently, we decided to present both factors f_C and f_C* in the revised manuscript, in order to avoid any confusion.

Also, it is not clear how many ice cliffs you detected on the entire debris-covered glacier tongue in both seasons, does this number vary? Did you observe the formation of new features over time or disappearance of them? This might also affect the p ratio, in case the cliff areas are not excluded in its calculation.

We added some information regarding the year-to-year evolution of the cliffs, in section 6.1 (see above). For the calculation of the factors f_C and f_C* we used the cliff footprint. Consequently, the dynamic changes in the cliff areas are taken into account.

Additionally, could you derive melt rates for the cliff surface (perpendicular to their surface) instead of pure elevation change rates? This would be helpful in order to compare your results to previous studies.

We added the backwasting distance in Table 1. We calculated it as individual cliff volume loss from terrestrial photogrammetry (i.e., only for the period Nov. 2015 – Nov. 2016), because this is the acquisition for which we know the mean cliff 3D area. The backwasting rate is compared with other studies in section 6.1.

3) Correction with local field of displacement

From the text I cannot follow how the rotational component of the ice cliffs/glacier surface are implemented in the calculations of the ice cliff volume changes (Section. 4.2). Since this is a main improvement of this study compared to an earlier one using a similar method, much more emphasis should be given to explain this implementation. How do you use the local field of displacement? Where does the 3D flow field that you use for the correction come from? This is a key comment that should be addressed for the paper clarity. A schematic figure would be helpful. Also, can you estimate how much the difference is compared to the previous method used in Brun et al. 2016? More importantly, can you validate the new method to show that it is appropriate and sound? From the short description provided: i) the method cannot be reproduced; ii) there is no evidence that it is the correct approach. You should discuss this new method in the discussion part of the manuscript, as it seems to be a clear advancement from previous studies, where a simple homogeneous direction of displacement was assumed.

Actually, taking into account the heterogeneity in the field of displacement has only little effect on the outcomes, because finally in our case study of Changri Nup Glacier, the rotational effect is limited. We added a supplementary figure (Fig. S5, see below) showing this. We added: "**This would be an important methodological refinement for ice cliffs on fast flowing glaciers with a rotational component, but has minor influence for the cliffs of interest in this study (Fig. S5)**". The main interest on this new method is its ability to handle gridded data, while the method of Brun et al. (2016) worked only with 3D (TINs) data. Taking into account the rotational effect is still an important improvement compared with Brun et al. (2016) especially if the method is used on fast moving and turning glaciers, which is not the case on Changri Nup or on Lirung glaciers (this study and Brun et al., 2016). Figure S5 helps also to visualize the method's development as well.

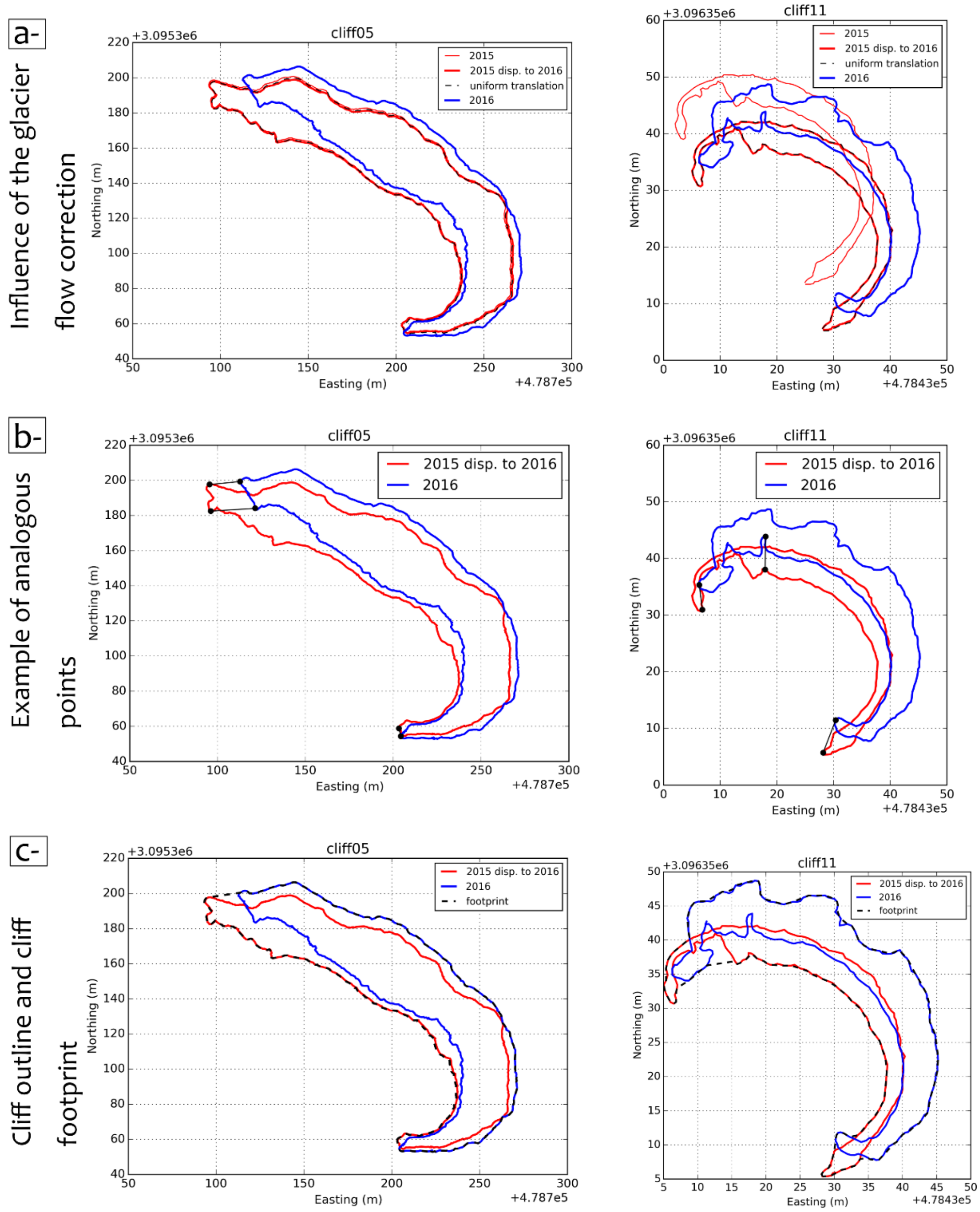

Fig. S5 - Examples of the methodological processing for cliff 05, located on a slow flowing area (left panels) and cliff 11, located in a fast flowing area (right panels). For all the panels the cliff outlines are represented in UTM45/WGS84. a- influence of the glacier flow correction, and comparison with a uniform translation. B- example of analogous points needed for the triangulation regularization. c- difference between the individual cliff outlines and the cliff footprint needed to calculate the cliff contribution for gridded data (DEMs).

4) Uncertainty of emergence velocity assumptions

As mentioned above in the general comments, the balance between ice cliff associated melt estimates and emergence velocity assumptions is not well elaborated in the manuscript. E.g. I miss a more in depth discussion of the uncertainties related to the calculation of the emergence velocities in the methods section, such as the one associated with having only one cross section profile for glacier thickness estimates, or general uncertainties in ice flux assumptions (glacier thickness measurements, bed topography, subglacial conditions, distribution of emergence etc.). As stated in line 19, p.10, “the main source of uncertainty on the cliff volume change is the uncertainty on the emergence velocity”, but this is not discussed later on in the text.

We added a paragraph about the uncertainty in the calculation for the emergence velocity (section 4.1):

“The emergence velocity refers to the upward flux of ice relative to the glacier surface in an Eulerian reference system (Cuffey and Paterson, 2010). For the case of a glacier in steady-state (i.e., no volume change at the annual scale), the emergence velocity balances exactly the net ablation for any point of the glacier ablation area (Hooke, 2005). For a glacier out of its steady state (as Changri Nup Glacier) the thinning rate observed in the ablation area is the sum of the net ablation and the emergence velocity (Hooke, 2005). On debris-covered glaciers, while the thinning rate is relatively straightforward to measure from DEM differences, for example, the ablation is highly spatially variable and difficult to measure (e.g., Vincent et al., 2016). In order to evaluate the mean net ablation of Changri Nup Glacier tongue from the thinning rate, we estimate the mean emergence velocity (w_e) for the period November 2015-November 2016 and for the period November 2016--November 2017 using the flux gate method of Vincent et al. (2016). As the ice flux at the glacier front is 0, the average emergence velocity downstream of a cross-section can we calculated as the ratio of the ice flux through the cross-section (Φ in $m^3 a^{-1}$), divided by the glacier area downstream of this cross-section (A_T in m^2):

$$w_e = \frac{\Phi}{A_T}$$

This method requires an estimate of ice flux through a cross-section of the glacier, and is based here on measurements of ice depth and surface velocity along a profile upstream of the debris-covered tongue (Figs. 1 and 2). The ice flux is the product of the depth-averaged velocity ($\overline{u}$ in $m\ a^{-1}$) and the cross-sectional area. For the period November 2015-November 2016 (resp. November 2016-November 2017), the glacier slowed down compared with the 2011-2014 period and the centerline velocity was equal to 10.8 $m\ a^{-1}$ (resp. 11.1 $m\ a^{-1}$), leading to an assumed mean surface velocity along the upstream profile of 8.1 ± 0.6 $m\ a^{-1}$ (resp. 8.3 ± 0.6 $m\ a^{-1}$), as the centerline velocity is usually 70 to 80 % of the mean surface velocity along the cross-section (e.g., Azam et al., 2012; Berthier and Vincent, 2012). We used the relationship between the centerline velocity and the mean velocity, instead of an average of the velocity field along the cross section, because the image correlation was not successful on a relatively large fraction (~ 30 %) of the cross section. Converting the surface velocity into a depth-averaged velocity requires assumptions about e basal sliding and a flow law (Cuffey and Paterson, 2010). Little is known about the basal conditions of Changri Nup Glacier, but Vincent et al. (2016) assumed a cold base, and therefore no sliding. This leads to $\overline{u}$ being approximated as 80 % of the surface velocity, additionally assuming n = 3 in Glen's flow law (Cuffey and Paterson, 2010). As an end-member case, assuming that the motion is entirely by slip implies $\overline{u}$ equals to the surface velocity (Cuffey and Paterson, 2010). Consequently, we followed Vincent et al. (2016) and assumed no basal sliding, but we took the difference between the two above-mentioned cases as the uncertainty on $\overline{u}$. This leads to $\overline{u}$ = 6.5 ± 1.6 $m\ a^{-1}$ (resp. 6.6 ± 1.7 $m\ a^{-1}$) for the period November 2015-November 2016 (resp. November 2016-November 2017).

Assuming independence for the cross-sectional area (σ_S) and the depth-averaged velocity ($\sigma_{\overline{u}}$), the uncertainty on the ice flux (σ_Φ) can be estimated as:

$$\frac{\sigma_\Phi}{\Phi} = \sqrt{\frac{\sigma_{\overline{u}}}{\overline{u}}^2 + \frac{\sigma_S}{S}^2}$$

Given the above mention values for the depth-averaged velocity, the cross-sectional area and the associated uncertainties, the relative uncertainty of the ice flux is ~30 %. As a result, for the period

November 2015-November 2016 (resp. November 2016-November 2017), the incoming ice flux was thus 499 700 ± 150 000 m^3 a^{-1} (resp. 503 840 ± 150 000 m^3 a^{-1}). The glacier tongue area was considered unchanged at 1.49 ± 0.16 km^2, corresponding to w_e = 0.33 ± 0.11 m a^{-1} (resp. 0.34 ± 0.11 m a^{-1}). It is notoriously difficult to delineate debris-covered glacier tongues (e.g., Frey et al., 2012). In this case, we assumed an uncertainty in the outline position of ± 20 m, leading to a relative uncertainty in the glacier area of 11 %, which is higher than the 5 % of Paul et al. (2013). In this case, the uncertainty on the glacier outline is not the main source of uncertainty in w_e, but for automatically delineated glacier outlines, this would be an important source of uncertainty. The updated emergence velocity is ~20 % lower than estimated for the 2011-2015 period (Vincent et al., 2016), due to both the thinning and deceleration of the glacier. As the difference in w_e between November 2015-November 2016 and November 2016-November 2017 is insignificant, we consider $w_e$to be constant and equal to w_e= 0.33 ± 0.11 m a^{-1} for the rest of this study. It is noteworthy that some spatial variability is expected for w_e, however, we have no means to assess it."

Also, the reduction in emergence velocity of _20% compared to the period 2010-2015 (line 16, p. 6) is striking, isn't it? Can you try to explain it more convincingly? If glacier emergence is so (relatively) variable, this might also have implications on your assumption of generally explaining the debris-cover anomaly by lower emergence velocities.
This reduction in emergence velocity is likely due to negative mass balances over this 2010-2017 period. Indeed, over the period 2010-17, we observe a strongly continuous negative glacier-wide mass balance of the debris-free West Changri Nup glacier of -1.36 m w.e. yr^{-1} (-1.24 m w.e. yr^{-1} between 2010 and 2015 from Sherpa et al., 2017; and unpublished data from P. Wagnon, for the period 2015-2017). Since Changri Nup and West Changri Nup glaciers are located near-by and since the time lag between negative surface mass balances and decreasing velocities is expected to be short (Vincent et al., 2000), the reduction in velocity between 2010-15 and 2015-17, and as a consequence in emergence velocity, is not surprising on Changri Nup glacier.
Nevertheless, we agree that the emergence velocity is likely to be variable both in time and space over Changri Nup Glacier (and elsewhere), but we do not have any clue to quantify this variability. That is the reason why we performed a sensitivity test over this emergence velocity, using a very large range of possible values (section 4.3.1 and fig. 6).

Azam, M. F., Wagnon, P., Ramanathan, A., Vincent, C., Sharma, P., Arnaud, Y., Linda, A., Pottakkal, J. G., Chevallier, P., Singh, V. B. and Berthier, E.: From balance to imbalance: a shift in the dynamic behaviour of Chhota Shigri glacier, western Himalaya, India, J. Glaciol., 58, 315–324, doi:10.3189/2012JoG11J123, 2012.

Berthier, E. and Vincent, C.: Relative contribution of surface mass-balance and ice-flux changes to the accelerated thinning of Mer de Glace, French Alps, over 1979-2008, J. Glaciol., 58, 501–512, doi:10.3189/2012JoG11J083, 2012.

Brun, F., Buri, P., Miles, E. S., Wagnon, P., Steiner, J. F., Berthier, E., Ragettli, S., Kraaijenbrink, P., Immerzeel, W. W. and Pellicciotti, F.: Quantifying volume loss from ice cliffs on debris-covered glaciers using high-resolution terrestrial and aerial photogrammetry, J. Glaciol., 62(234), 684–695, doi:10.1017/jog.2016.54, 2016.

Brun, F., Berthier, E., Wagnon, P., Kaab, A. and Treichler, D.: A spatially resolved estimate of High Mountain Asia glacier mass balances from 2000 to 2016, Nat. Geosci., 10, 668–673, 2017.

Cuffey, K. M. and Paterson, W. S. B.: The physics of glaciers, Academic Press., 2010.

Frey, H., Paul, F. and Strozzi, T.: Compilation of a glacier inventory for the western Himalayas from satellite data: methods, challenges, and results, Remote Sens. Environ., 124, 832–843, doi:http://dx.doi.org/10.1016/j.rse.2012.06.020, 2012.

Herreid, S. and Pellicciotti, F.: Automated detection of ice cliffs within supraglacial debris cover, The Cryosphere, 12(5), 1811–1829, doi:10.5194/tc-12-1811-2018, 2018.

Hooke, R. L.: Principles of glacier mechanics, Cambridge university press., 2005.

Paul, F., Barrand, N. E., Baumann, S., Berthier, E., Bolch, T., Casey, K., Frey, H., Joshi, S. P., Konovalov, V., Le Bris, R., Mölg, N., Nosenko, G., Nuth, C., Pope, A., Racoviteanu, A., Rastner, P., Raup, B., Scharrer, K., Steffen, S. and Winsvold, S.: On the accuracy of glacier outlines derived from remote-sensing data, Ann. Glaciol., 54, 171–182, doi:10.3189/2013AoG63A296, 2013.

Sherpa, S. F., Wagnon, P., Brun, F., Berthier, E., Vincent, C., Lejeune, Y., Arnaud, Y., Kayastha, R. B. and Sinisalo, A.: Contrasted surface mass balances of debris-free glaciers observed between the southern and the inner parts of the Everest region (2007-2015), J. Glaciol., 63(240), 637–651, 2017.

Vincent, C., Vallon, M., Reynaud, L. and Le Meur, E.: Dynamic behaviour analysis of glacier de Saint Sorlin, France, from 40 years of observations, 1957-97, J. Glaciol., 46, 499–506, doi:10.3189/172756500781833052, 2000.

Vincent, C., Wagnon, P., Shea, J. M., Immerzeel, W. W., Kraaijenbrink, P., Shrestha, D., Soruco, A., Arnaud, Y., Brun, F., Berthier, E. and Sherpa, S. F.: Reduced melt on debris-covered glaciers: investigations from Changri Nup Glacier, Nepal, The Cryosphere, 10(4), 1845–1858, doi:10.5194/tc-10-1845-2016, 2016.

Watson, C. S., Quincey, D. J., Smith, M. W., Carrivick, J. L., Rowan, A. V. and James, M. R.: Quantifying ice cliff evolution with multi-temporal point clouds on the debris-covered Khumbu Glacier, Nepal, J. Glaciol., 63(241), 823–837, 2017.